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Accumulation of Cadmium by the American Oyster, 'Crassostrea virginica'

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We have demonstrated that 5 mg/l of cadmium can be accumulated from seawater by adult oysters to levels exceeding 13 mg/l wet weight, a level found to cause illness in man. Bioaccumulation of cadmium concentrations greater that 13 mg/l wet weight occurs in about 40 weeks when exposed to 5 mg/l cadmium during winter, spring and summer conditions. Oysters accumulated more that half the total cadmium during the summer months.

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Accumulation of cadmium by the American oyster, *Crassostrea virginica*

CADMIUM is a major environmental pollutant potentially harmful to health, and if the sea becomes polluted with this metal there could be a reduction in extensive sources of food[1]. Seafoods constitute a source of cadmium in the human diet[2] and in view of abundant evidence that shellfish accumulate trace metals[3–6], it is important to investigate cadmium pollution. People have become ill from cadmium poisoning after ingesting foods containing concentrations of 13–15 μg g^{-1} (13–15 p.p.m., ref. 7). We now report that adult oysters reared in seawater containing 0.005 p.p.m. cadmium accumulated up to 10.75 p.p.m. in 40 weeks. This accumulation, plus cadmium naturally present, brought the concentration of cadmium to 13 p.p.m. in the soft tissue, which represents a potential health hazard if oysters constitute a major item of the diet.

Three-year-old oysters, *Crassostrea virginica*, were obtained from Long Island Sound in October 1972. The mean shell length was 10.2 cm with a mean whole wet meat weight of 8.1 g. The animals were acclimatised for 1 month, in six fibreglass troughs, each measuring 3.75 m × 30 cm × 25 cm deep and supplied with flowing unfiltered seawater (30‰ salinity, ambient temperature of 1.5 °–23 °C) at a rate of 16 l min^{-1}. Each trough held 50 oysters on a false bottom consisting of polyethylene grids resting on polyvinylchloride pipe about 2.5 cm above the bottom.

After acclimatisation of the oysters, three troughs received a cadmium chloride solution ($CdCl_2 \cdot 2.5\ H_2O$) and three troughs served as controls. The seawater–cadmium stock solution contained 0.016 mg Cd per ml and was pumped at the rate of 5 ml min^{-1} to give, when mixed with incoming seawater entering at a rate of 16 l min^{-1}, a calculated concentration of 0.005 p.p.m. cadmium. Samples of water were taken from the troughs weekly, concentrated by a Chelex resin technique developed by Dr Earl Davey of our laboratory and assayed by atomic absorption spectroscopy. A range of values from 0.0047 to 0.0053 p.p.m. was found in the seawater from the experimental troughs and 0.0001–0.0002 p.p.m. was found in the control samples. Throughout this study, the animals received no supplementary food because the seawater supplied to the troughs apparently contained sufficient food organisms. Mortality was negligible in both control and experimental groups.

Every 4 weeks, five oysters were removed from the experimental and control groups. They were shucked and the shell liquor and body fluids were retained with the whole wet meats. The meats were weighed, dried at 100 °C for 24 h and ashed at 25 °C for 18 h. After cooling, 10 ml of concentrated HNO_3 was added to the ashed samples which were then dried at 100 °C for 24 h and ashed for 18 h. When necessary, ashing and treatment with HNO_3 were repeated until a clean white ash was obtained. The final ash was dissolved in 5% HNO_3 and analysed for cadmium by atomic absorption spectroscopy. The results were expressed as μg of cadmium per g (p.p.m.) for both wet and dry weights.

A mean of 2.72 μg cadmium per g wet weight was found in oysters immediately after collection. Concentrations of cadmium in seawater at the sampling site were 0.0001–0.0002 p.p.m. Although the dry weight data show that *C. virginica* can accumulate cadmium regardless of the time of year, the rate of accumulation in summer (July to August) was more than double that of the winter and spring (Table 1): at this time the warmer seawater supported a greater metabolic rate so that more seawater passed over the gills[8]. From July 4 to August 29, the experimental oysters accumulated 45% of the cadmium present by the end of 40 weeks (Table 1). Oysters exposed to 0.0005 p.p.m. cadmium for 40 weeks from November 19 to August 29 accumulated a mean of 10.75 μg cadmium per g wet weight (Table 1).

Although we have observed that apparently unpolluted seawater contains less than 0.001 p.p.m. of cadmium, values equal to and exceeding 0.01 p.p.m. have been recorded in seawater and freshwater[9,10] and also in waters from which oysters have been collected[11]. The high level of cadmium contamination in estuarine waters is exemplified in Corpus Christi Harbor where as much as 0.078 p.p.m. has been reported[12]. Therefore, we felt that exposure of oysters to 0.005 p.p.m. cadmium was realistic because such concentrations can be found in the marine environment.

Increased cadmium concentrations seem to be due mainly to trace metal entering estuarine or coastal areas from industrial effluents and rivers. Ratkowsky *et al.*[6] found a close correlation between proximity to heavily urbanised areas and the concentration of metals in oysters: those growing near urban areas had the greatest concentration of one or more metals. Shuster and Pringle[5] found concentrations of 0.1–7.80 p.p.m. cadmium (mean 3.10 p.p.m.) in whole wet meats of oysters sampled along the Atlantic coast of the USA. The freshly collected oysters we used contained between 1.78 and 3.78 p.p.m. cadmium wet weight (mean 2.72 p.p.m.).

Table 1 shows that oysters exposed to 0.005 p.p.m. cadmium for 40 weeks accumulated concentrations of cadmium (13–15 p.p.m. wet weight) that could have the same effect on man as foods containing 13–15 p.p.m. (ref 7). The emetic property of cadmium in excess of 13–15 p.p.m. in ingested foods[7] is a physiological protective mechanism. But concentrations less than 13–15 p.p.m. in foods are also of concern because 5–10% of cadmium ingested by humans is absorbed and retained for

Table 1 Cadmium in whole meats of *Crassostrea virginica* after exposure to 5 parts per 10^9 Cd^{2+} for 40 weeks (November 1972 to August 1973) in flowing unfiltered seawater

Date	Time (weeks)	Mean biweekly temperature (°C)	μg Cd per g wet weight		μg Cd per g dry weight	
			Control	Experimental	Control	Experimental
1973						
November	0	10.0	2.72	2.72	11.83	11.83
December	4	4.3	2.48	3.60	13.10	21.75
1974						
January	8	2.8	2.58	4.02	15.57	22.00
February	12	3.2	3.11	4.14	19.35	24.90
March	16	4.3	2.10	4.96	13.42	28.55
April	20	7.2	2.62	5.29	13.60	27.59
May	24	11.1	2.81	4.76	16.75	33.77
June	28	16.4	1.93	5.71	10.85	39.22
July	32	20.2	1.65	9.10	12.19	63.27
August	36	21.1	1.76	10.37	17.47	85.83
August	40	22.6	1.69	13.57	12.55	104.91

many years, chiefly in the kidneys (its biological half life is 16–33 yr)[1]. Consequently, cadmium has been implicated as a possible cause of hypertension[13] through damage to the renal cortex[1].

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